Jet Propulsion Laboratory
California Institute of Technology

EXperiments Along Coexistence near Tricriticality

Melora Larson [a], Norbert Mulders [b],
Al Nash [a], and Masoud Mohazzab [b]

[a] Jet Propulsion Laboratory, California Institute of Technology
[b] University of Delaware

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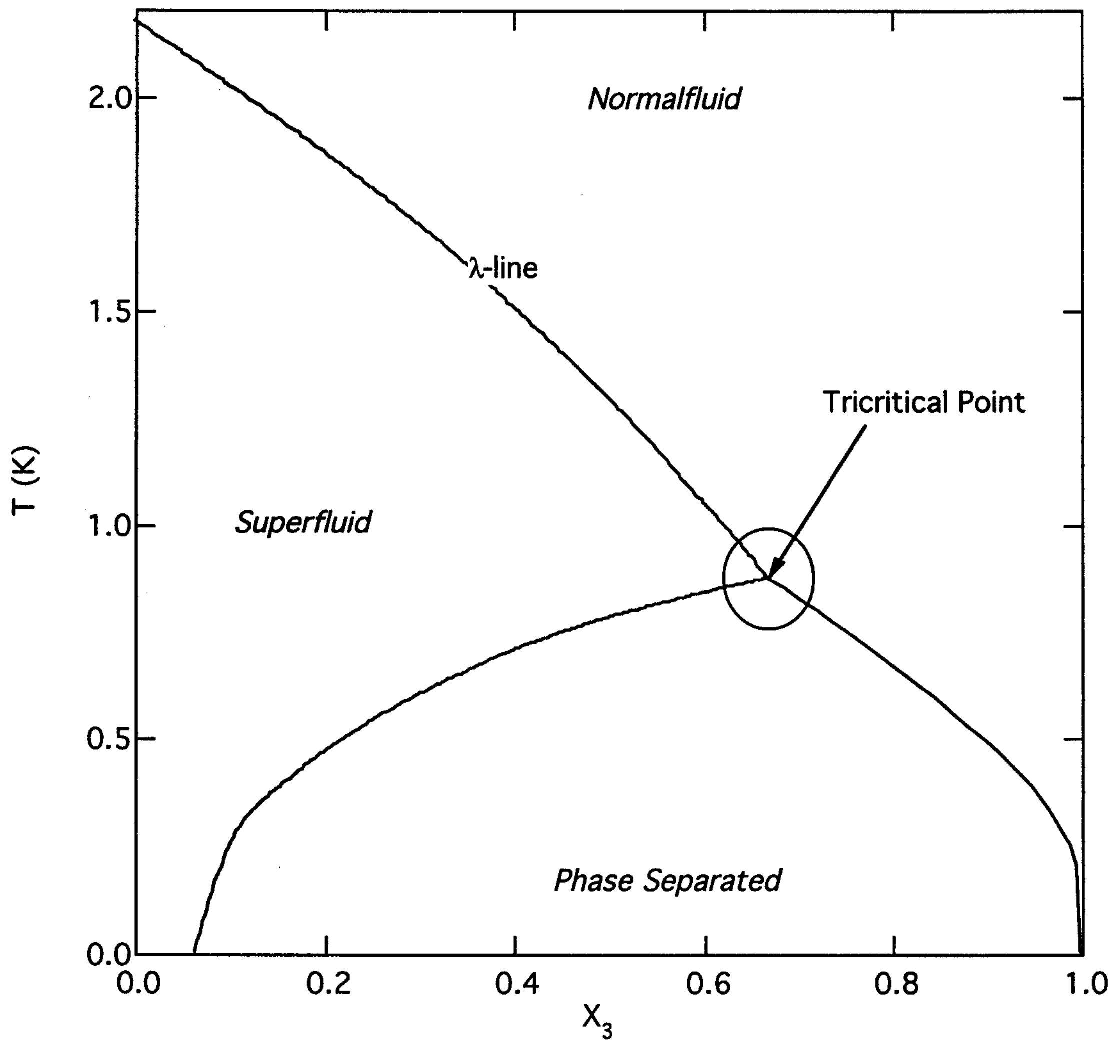
Helium Mixture Phase Diagram



Why Study the Tricritical Point

- Tricritical points are model systems with 2 control parameters
- Theoretical predictions are exact for 3D tricritical points
  - predict integer fractions for the critical exponents
  - Predict logarithmic corrections to the power laws
- Existing experimental measurements not as accurate as at critical points
- Significant new technology available since previous work, 15-20 years ago
  - Higher resolution/stability thermometry
  - Improved second sound detectors

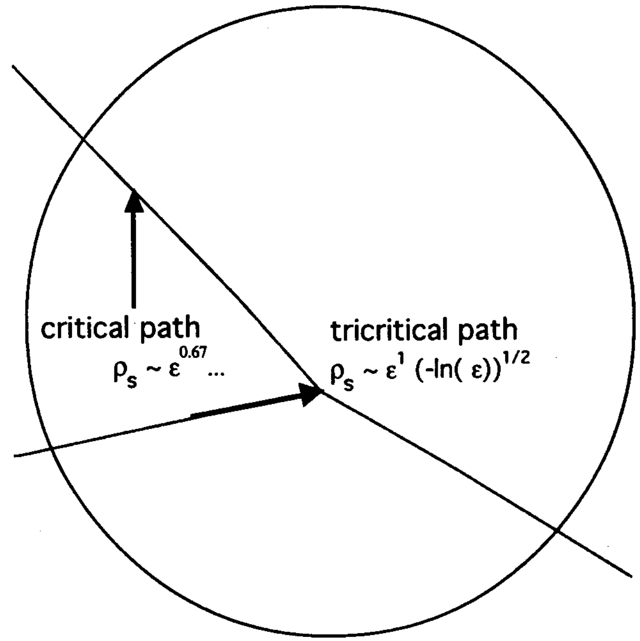
Experimental Objectives

- Second sound measurements along the coexistence curve

$$\rho_s/\rho = \kappa_\sigma \, \varepsilon_t^{\,\zeta_\sigma} \, |\ln \varepsilon_t|^y$$

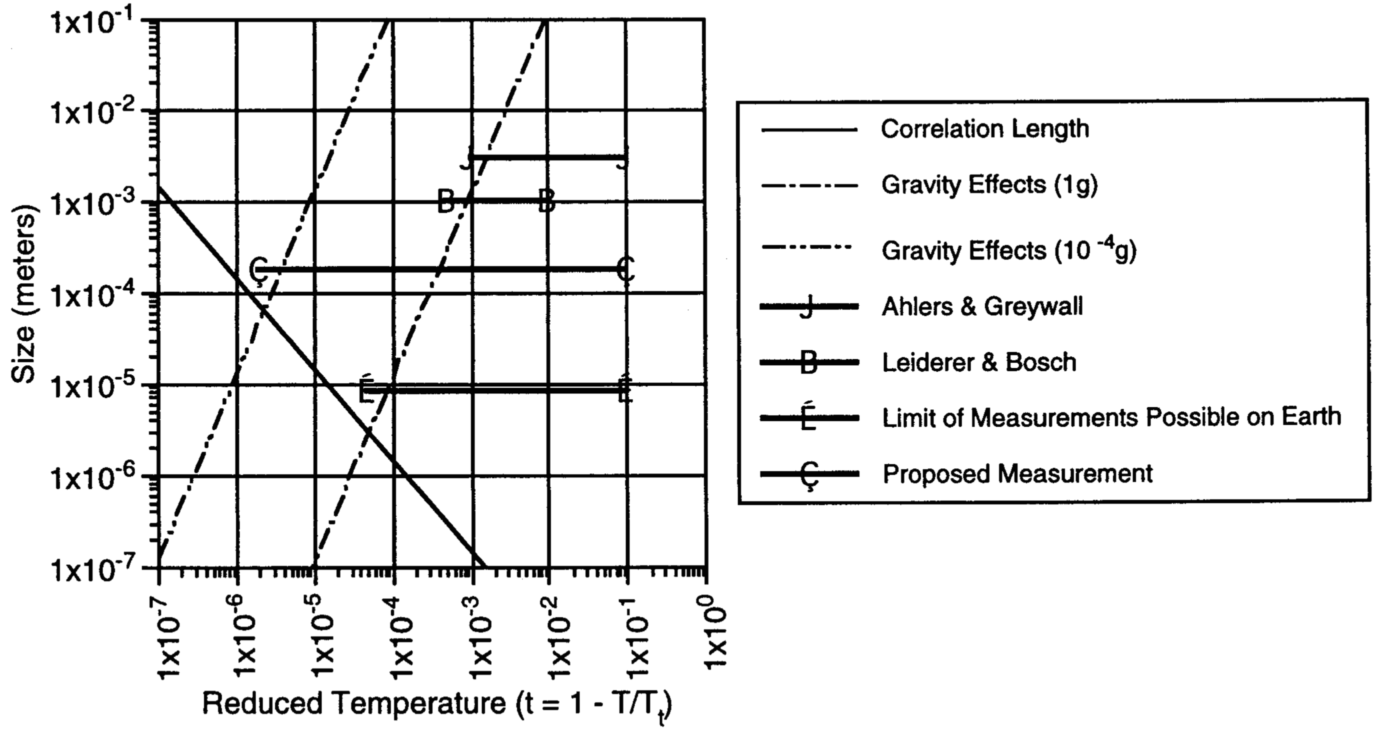
$$\zeta_\sigma = 1, \; y = 1$$

- Shape of the phase boundaries
  - power laws (exponents of 1) with logarithmic corrections

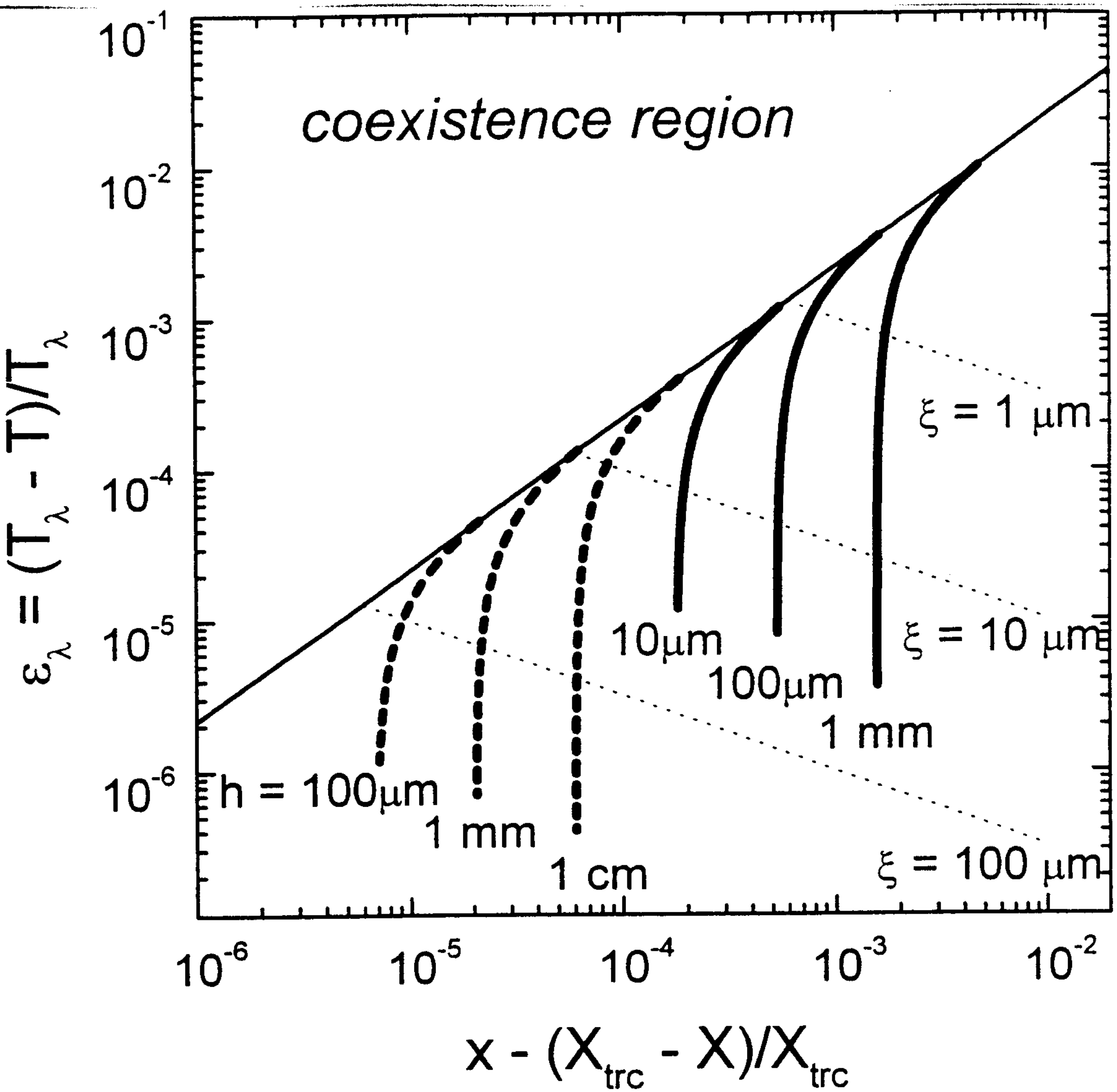


Limitations Imposed by Gravity

- Concentration susceptibility diverges at tricritical point
  - small cell
- $\xi_0(X)$ diverges at tricritical point
  - large cell



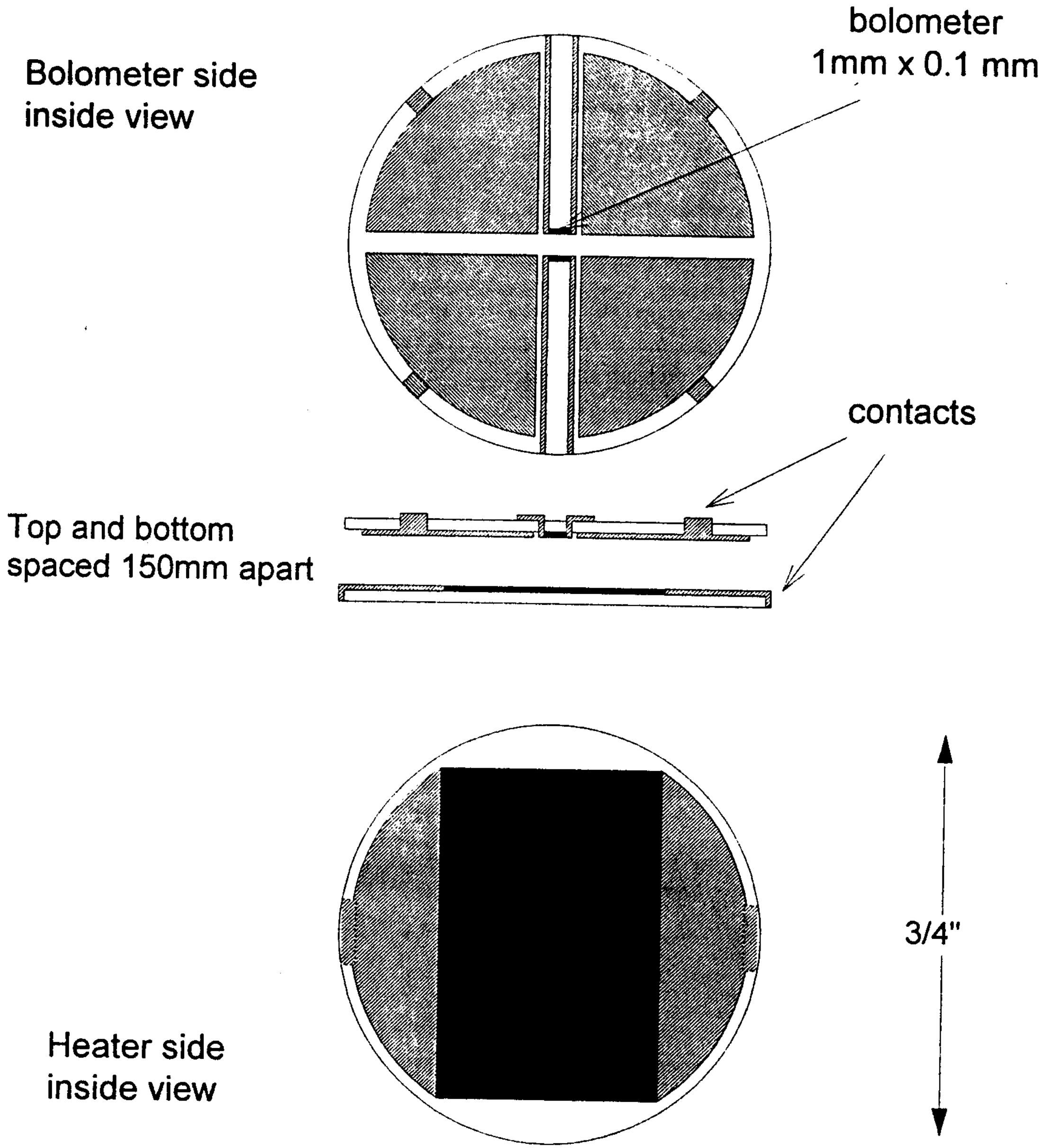
Gravity Effects: Concentration versus reduced T



Other Complications

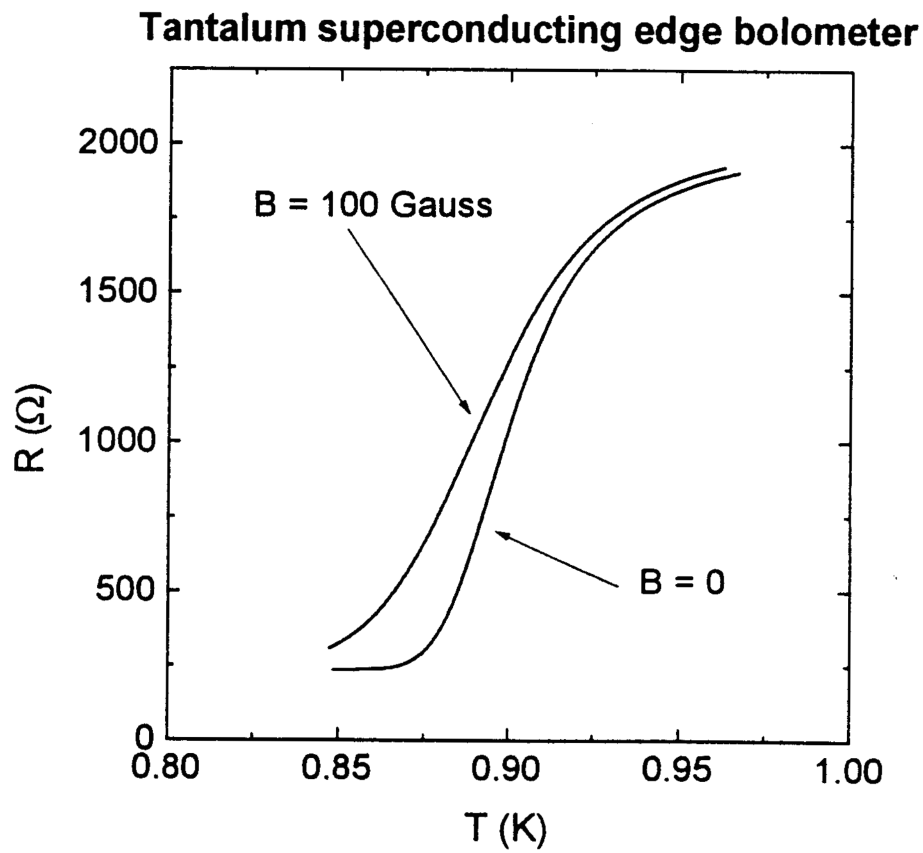
- The superfluid density is very small
  - Large counter flow velocities
  - Small second sound signals
  - Finite size effects become strong
- Long relaxation times
- Combined with gravity effects, sets experimental procedure
  - Thin flat cell
  - Pulsed time of flight second sound measurements

Experimental Cell



Second Sound Detection

- Superconducting transition edge bolometers
  - Very thin films of tantalum
    - Reproducible properties
    - Transition can be shifted by magnetic field
    - High sensitivity



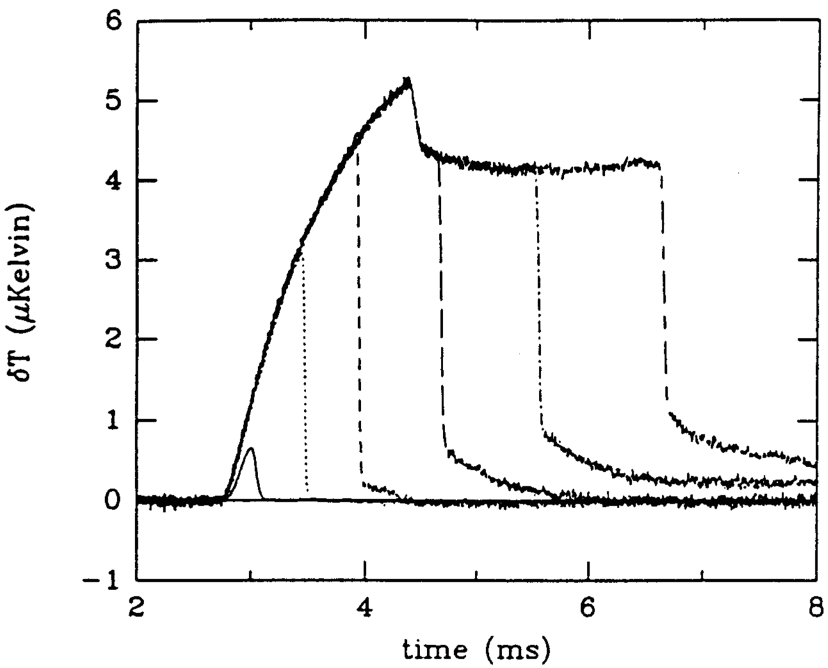
Non-Linear Second Sound

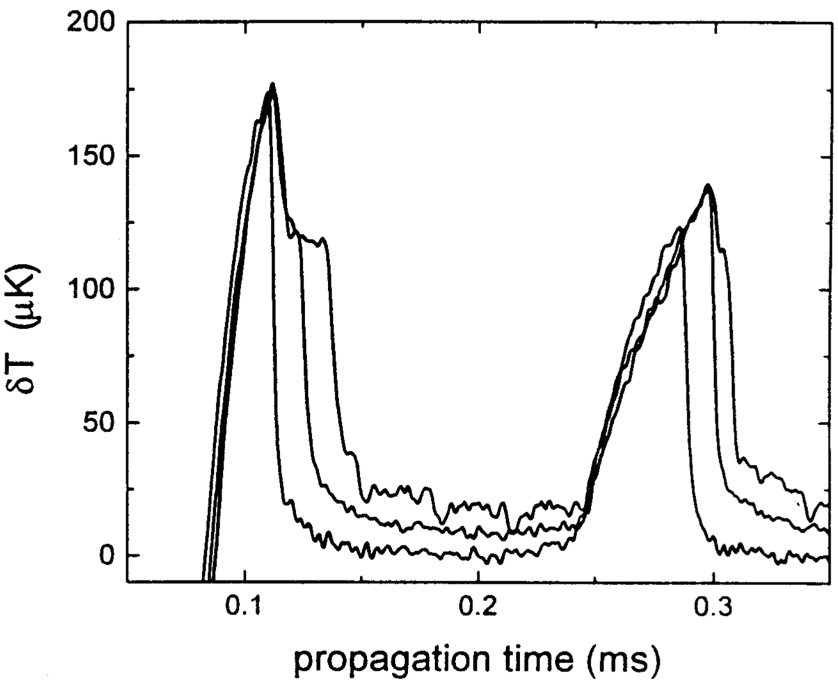
- Even at moderate distances to tricritical point
  - Second sound is very non-linear
    - Formation of shock tails
    - Large heat pulses
      - Saturation of second sound signal
        - » Previously seen in bulk helium-4, very close to T_λ
  - Signals sensitive to bolometer power dissipation
    - Heat flush effect decreases ^3He around bolometer
      - Speed of second sound increases
      - Large enough bolometer powers
        - » Signal splits
        - » One path through ^3He depleted region
        - » Other path through unaffected regions

Non-linear Saturation Effects

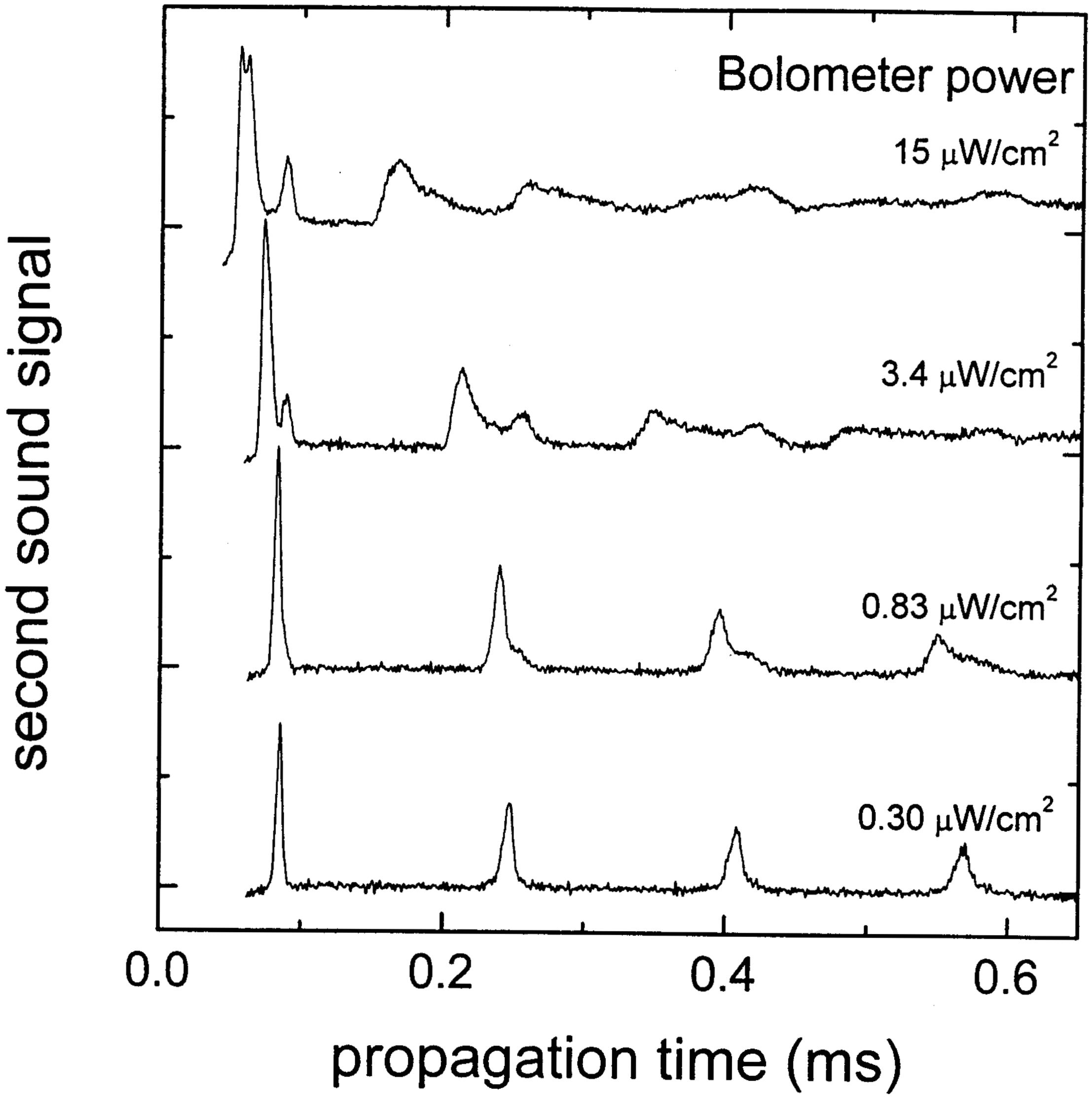
- Pure ^4He
  - T_λ -T = 10μK
  - heat pulse: 0.28ms
  - Heat flux from: 0.058 to 7.77 mW/cm^2

- ^3He-^4He Mixture (X_3=0.66)
  - T_λ -T = 2.5mK
  - heat pulse: 10, 15, & 20 μs
  - Heat flux: 64 mW/cm^2



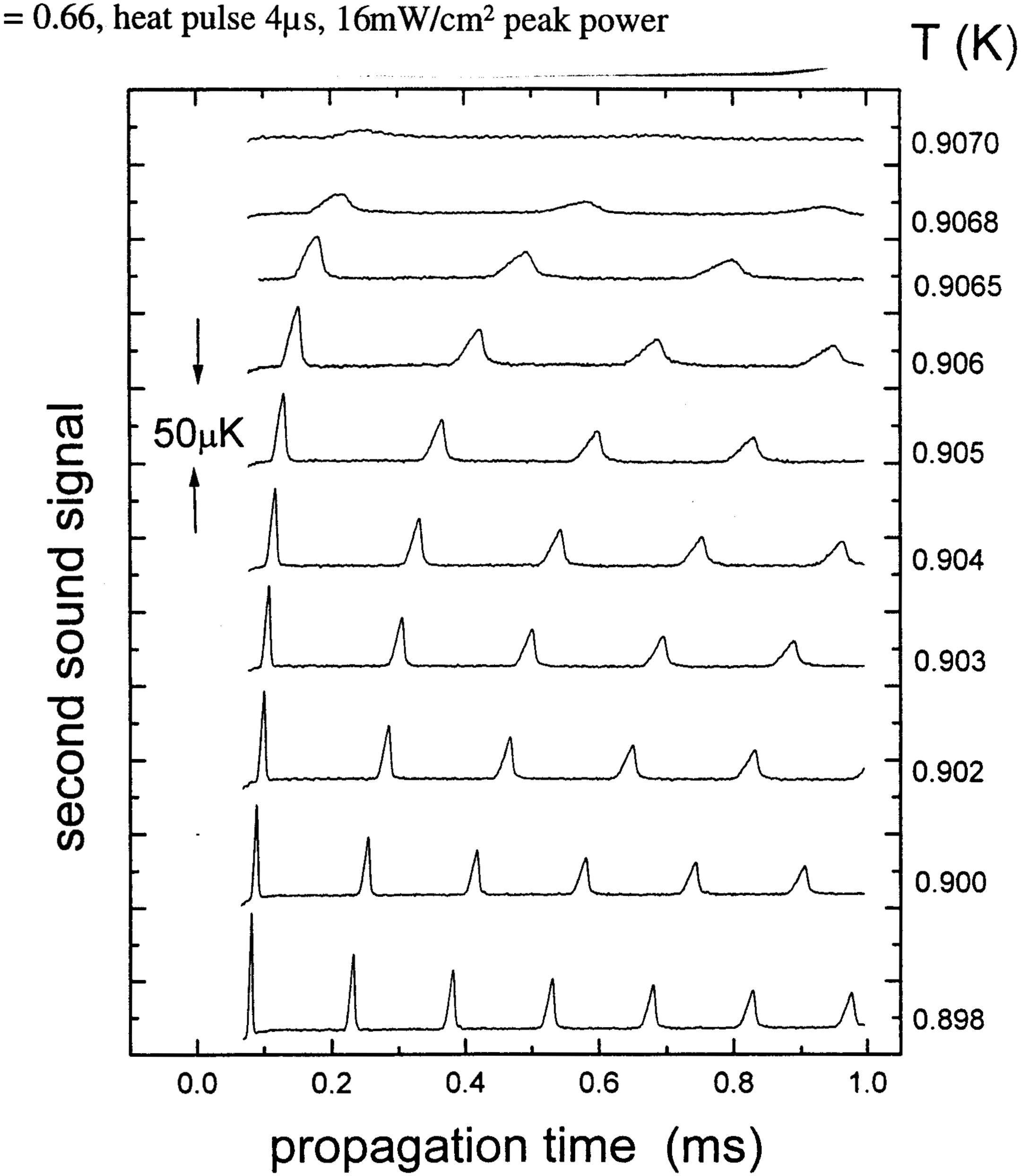


Bolometer Power Effect



Second Sound Approaching the Tricritical Point

- $X_3 = 0.66$, heat pulse 4μs, 16mW/cm^2 peak power



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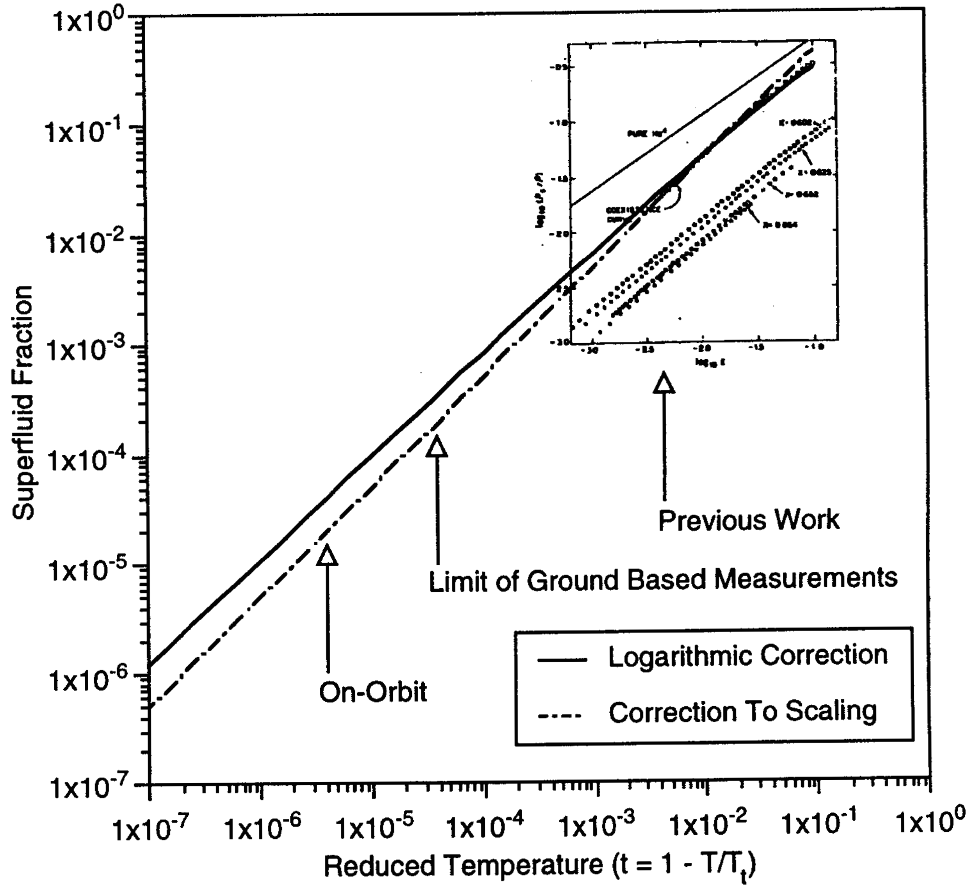
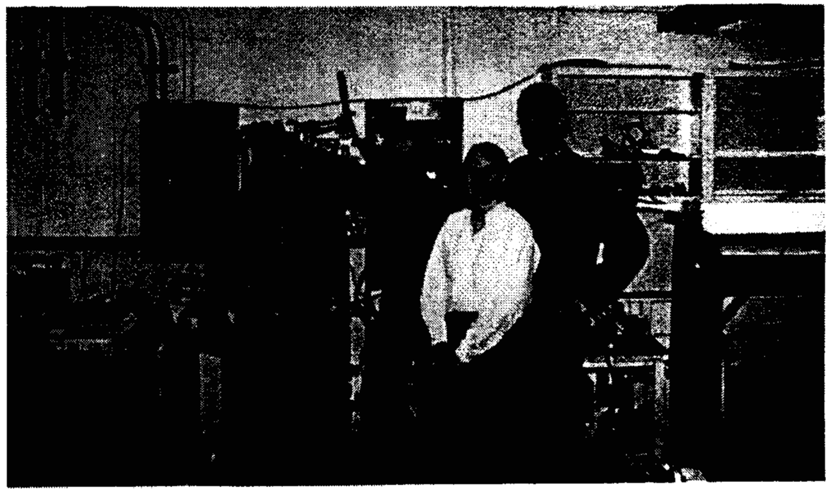
Summary: Superfluid Density

- Ground based measurements will improve existing data by over one decade in reduced temperature
- Flight measurements will extend data another decade
- Will be able to distinguish logarithmic corrections from corrections to scaling



Conclusions and Plans

- Tricritical point is a rich area of study
- Tricritical behavior provides rigorous test of exact theoretical predictions of RG
- Modern technology can be applied to reach the fundamental measurement limits



- Refine the data reduction and anaylsis
  - Include the non-linear effects
- Finish the JPL sub-Kelvin facility
  - Technology development
  - Second science probe
- Refine the flight parameters